ABSTRACT

PRESENTATION ON JSC 737 AIRCRAFT FLAMMABILITY TESTING

The FAA has requested NASA/JSC to perform approximately 20 component and full-scale tests in a 737 fuselage located at JSC to provide validation data or indicate changes that need to be made to a fire math model (Dayton Aircraft Cabin Fire Model) developed for the FAA.

The instrumentation required for this test program is more extensive than in previous full-scale tests and in some cases is based on undeveloped techniques; therefore, some preliminary tests were conducted to evaluate the adequacy of planned instrumentation.

The objectives of the program were met in that it was verified that propagation of a fire could be determined from the sequential response of thermocouples located on a test specimen (such as a seat), and continuous weighing of the specimen during the test was accomplished. In addition, two different techniques for measuring smoke density were found to be comparable.

JSC/FAA INSTRUMENTATION VALIDATION TESTS

INTRODUCTION

The FAA has requested NASA/JSC to perform approximately 20 component and full-scale tests in a 737 fuselage located at JSC to provide validation data or indicate changes that need to be made to a fire math model (Dayton Aircraft Cabin Fire Model) developed for the FAA.

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This report covers the results of these preliminary tests.

OBJECTIVES

The primary objective of these preliminary tests was to evaluate instrumentation techniques planned for use in a subsequent joint program with the FAA. The specific objectives were as follows:

1. Evaluate tracking of flame propagation on burning materials by the appropriate location of thermocouples on a given test specimen.
2. Measure the burning rate of the flammable materials (of a given test specimen) during the test by continuous weighing of the test specimen.
3. Evaluate the NBS photometric smoke measurement system and compare its results to those of a laser smoke measurement technique.
4. Evaluate the capability of a recently developed bidirectional gas flow device for measuring variable gas flows during flammability tests.
5. Collect gas samples and measure quantities for six gases (O_2, CO_2, CO, HF, HCN, and HCL).

TEST DESCRIPTION

Tests were conducted in a 737 fuselage utilizing jet A-1 fuel as the ignition source. The initial test specimen consisted of a mockup aircraft seat with state-of-the-art fire resistant aircraft seat cushion foam in the configuration shown in figure 1. The ignition source was one liter of jet A-1 fuel in a pan 12" x 12" located as shown in figure 1. The seat was suspended from a load cell with a cable and bridle system as shown in figure 1. To prevent excessive sidewise movement of the seat due to air currents, four right angle tabs were fastened to the floor at each leg position with approximately 1/4" clearance between the tab and leg. The bottom of each chair leg was approximately 1-1/2" above the aircraft floor to prevent contact with the floor due to support cable thermal expansion.

INSTRUMENTATION

The following instrumentation was installed on the seat and in the 737 fuselage:

1. Thermocouples - The seat foam for the initial test was instrumented with thermocouples as shown in figure 2. A temperature probe was located above the fuel pan to indicate approximate flame temperatures. Additional thermocouples were located on two thermocouple trees as shown in figure 3.

2. Load Cell - A 0-100 pound load cell was suspended from a bracket outside the fuselage directly above the seat position. A cable from the load cell traversed through a tube that penetrated the fuselage. A bridle attached at four points of the chair converged to a point directly above the chair C.G. where it was attached to cable suspended from the load cell (figure 1).

3. Smoke Measuring Equipment - Two devices were installed in a close proximity (figure 3) to measure the loss of visibility due to smoke production. A laser source located 3 feet from the sensor was used along with an NBS photometric smoke measurement system which has a light source one meter from the sensor.

4. Bidirectional Gas Flow Probe - A gas flow probe based on differential pressure was located as shown on figure 3.

5. Movie Cameras - Two movie cameras were located as shown in figure 3 to photograph the seat during the test. Color film was used at 24 frames per second (realtime) in both cameras.

6. Still Photography - Still color photographs of the test specimen were taken before and after the initial test.

7. Gas Collection and Analysis - Dry gas samples were collected for laboratory analysis by gas chromotography for O_2, CO_2, and CO. Samples were also collected in a bubbler system containing an aqueous solution for subsequent analysis for HF, HCN, and HCL. A more detailed description of the gas collection and analytical techniques and results is given in Figs. 4-5.

TEST RESULTS

After ignition of the jet A-1 fuel (that is, when the fire completely covered the fuel pan area), approximately one minute elapsed prior to significant involvement of the foam in the fire. The jet fuel and foam produced large quantities of smoke that obscured camera visibility approximately 1-1/2 minutes after ignition. The foam melted as it burned, which resulted in the dripping of many flaming particles. The fire burned out after approximately 6 minutes, and, although all of the seat bottom was gone, a large portion of the back remained as shown in figure 6. The pre-test weight of the foam was 6.4 lbs and post-test weight of the remaining foam was 2.2 lbs for a total weight of foam burned or melted of 4.2 lbs.

Thermal Data - The temperature response and location of four centrally located thermocouples on the seat cushion and back for the first 5 minutes of the test are shown in figure 7. Peak temperatures were 1200 to 1400°F, occurring from 1 minute to 2 minutes when all of the temperatures gradually went down. This was apparently due to the foam and direct flame impingement receding from the thermocouples as the foam was consummed.

One of the test objectives was to determine the feasibility of tracking fire propagation through thermocouple response; figures 7 thru 12 are presented with this objective in mind. Since most of the thermocouples on the foam responded in the first 90 seconds, the time span used on figures 8 thru 10 is 100 seconds rather than the full five minutes used on the other figures. This expanded time scale permits a better view of the point in time at which the rapid temperature rise indicates flame impingement on the thermocouple. Figure 6 shows the spread of fire reaching four thermocouples on the seat cushion bottom. Thermocouple 3 is closest to the fire and on the side to which the air flow tends to direct the fire and consequently is the first to rise. Its initial reading of 250°F results from calling "time zero" the time at which the fuel pan is covered with fire, which is usually several seconds after ignition because of the slowness of jet A-1 to ignite. Temperatures from thermocouples 2, 4, and 1 follow in expected order based on the fire location and air flow pattern. The other three thermocouples on the seat bottom (figure 12, thermocouples 5, 6, and 7) do not show a significant spread in time. The opposite pattern occurs on the top of the same seat cushion, as shown in figures 8 and 9, and, as would be expected, the temperature rises occur 30-45 seconds later than on the bottom. All thermocouples on the fireside of the seat cushion back show a fairly definite and well spread point in time where a significant temperature rise occurs on this surface. Figure 11 shown the relatively lower temperatures occurring on the back side of the seat back as would be expected from the limited damage on this surface (as shown in figure 6).

Weight Loss Data - The weighing of the seat frame and foam during the initial test to determine the burning rate of the foam resulted in anomalous data. A weight loss of approximately 3 times the weight of the foam apparently resulted from some constraint or friction between the seat legs and the restraining tabs.

Additional tests resulted in weight loss close to that expected. A test was conducted using a non fire-retardant polyurethane foam which produced a weight loss with respect to time as shown in figures 13-14. An additional test was conducted with a much slower burning fuel (2-1/2 liters of jet A-1 in an 18" x 18" fuel pan located on top of the seat) with the results shown in figure 15. Both tests produced inherent minor inaccuracies concerning actual weight loss due to burning. While the foam was burning, considerable melting and dripping of flaming particles occurred, resulting in some weight loss of material that may not have been due to burning. The burning liquid fuel floats on water and after a period of time the water starts boiling, resulting in weight loss in addition to that of the burning fuel. The weight loss of the water can be determined after the test but not the rate or time of loss.

Smoke Density - A laser system and an NBS smoke density measuring system were used to measure the loss of visibility due to smoke during the initial test (fire retardant polyurethane foam). The comparative results are shown in figure 15. The initial levels of smoke density of 17% and 25% are mainly due to the smoke evolved from the hot ignitor prior to ignition of the fuel and during the time the flames cover the fuel pan. The laser system has a time delay smoothing circuit in the electronics which may account for the somewhat smoother data.

CONCLUDING REMARKS

Tests were conducted to evaluate instrumentation techniques for a subsequent joint program with the FAA. Most of the test objectives were met or a need for further testing established. As indicated by the test results, tracking of flame propagation across burning materials can be determined from temperature response of thermocouples located on the test specimen. Weighing of test specimens and determining the burning rate of materials during the test was achieved. Care must be exercised to insure that the test specimen being weighed does not have any external interference, otherwise inconsistent results occur.

Measurements of smoke density provided by the laser technique and NBS smoke measuring system were in fairly good agreement. A time delay smoothing circuit in the laser system provided more uniform data than the NBS system. Similar circuitry could be applied to the NBS system; however, eliminating significant excursions in the data may or may not be desirable.

Results of the gas flow measurements are inconclusive at this time. Further effort is planned in this area with some additional baseline air flow and flammability tests.

The time that elapses after ignition, but prior to full involvement of the ignition fuel results in premature response of thermocouples close to the fuel pan and also of the smoke density measurement system. A more rapid coverage of the fuel pan by the fire is desirable and an attempt to achieve this is being made.

The overall results indicate that the instrumentation planned for the JSC/FAA test program will provide useful data that will support the validation or indicate necessary changes to the fire math model.

JSC/FAA TEST PROGRAM INSTRUMENTATION VALIDATION TESTS

SEAT CUSHION FOAM TEST

OBJECTIVES

- o EVALUATE TRACKING OF FIRE PROPAGATION WITH THERMOCOUPLES
- o DETERMINE BURNING RATE DURING TEST
- o COMPARE VISIBILITY MEASUREMENTS WITH LASER & NBS TECHNIQUE
- o EVALUATE FACTORY MUTUAL TECHNIQUE FOR MEASURING GAS FLOW
- o ASSESS HAZARD OF STATE-OF-THE-ART SEAT FOAM
- o DETERMINE COMPATIBILITY OF DATA FORMAT WITH DACFIR MATH MODEL

TEST CONFIGURATION

- 20-FOOT TEST SECTION
- SEAT SUSPENDED FROM LOAD CELL
- BOTTOM AND BACK SEPARATED TO REDUCE CROSS EFFECTS
- ONE QUART OF JET A1 IN 12 INCH SQUARE PAN

INSTRUMENTATION

37 THERMOCOUPLES ON FOAM SEAT AND BACK

3 FOOT LASER AND 1 METER NBS APPARATUS IN CLOSE PROXIMITY

LOAD CELL FOR CONTINUOUS SEAT WEIGHING

FACTORY MUTUAL SYSTEM FOR LOW GAS FLOW MEASUREMENT

GAS COLLECTION AND ANALYSIS FOR NCN, HCL, HF, CO, CO_2, AND O_2

TWO COLOR MOVIE CAMERAS (24 FPS)

TV CAMERA

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SEAT TEST CONFIGURATION

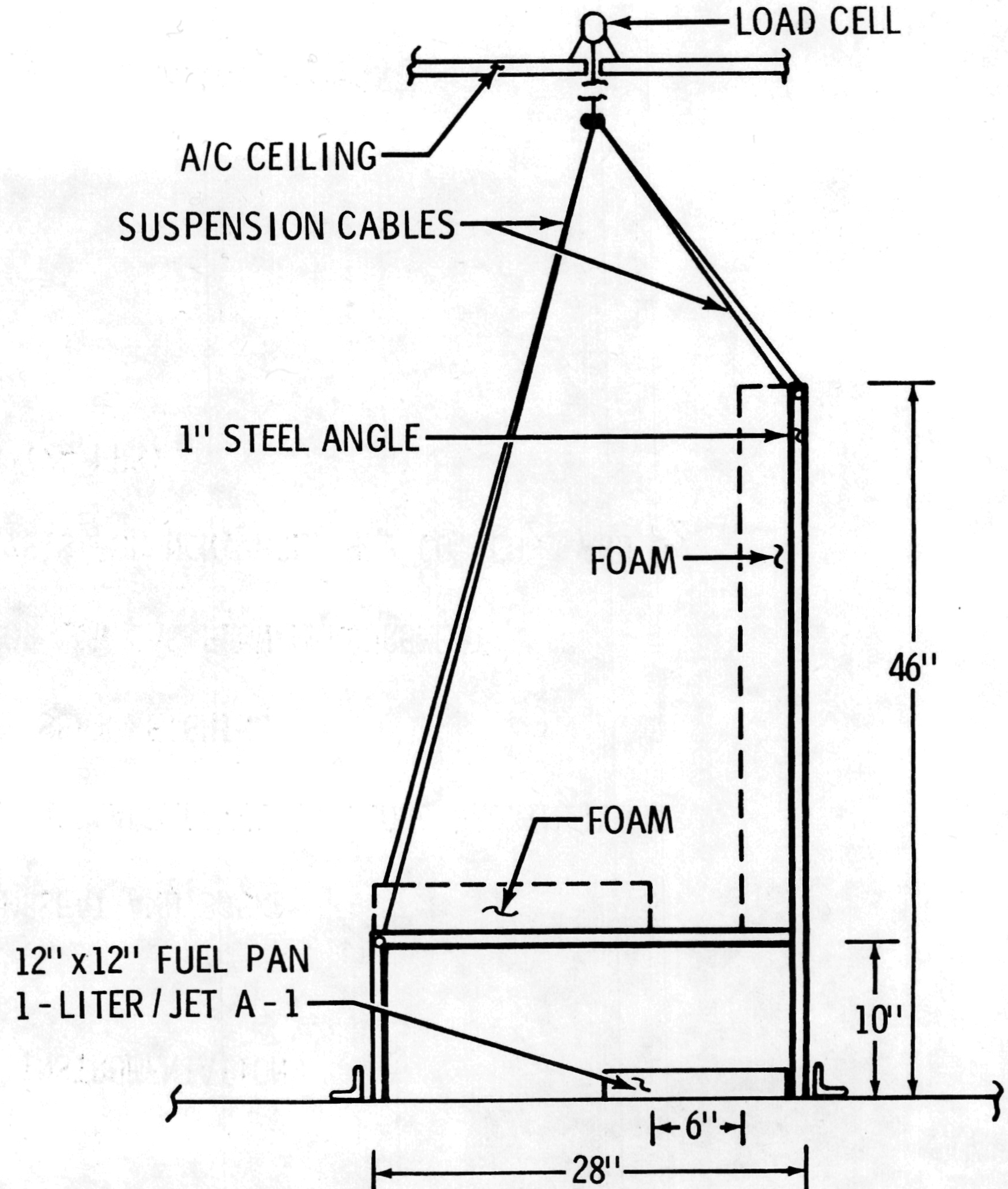

Fig. 1

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INSTRUMENTATION

SEAT BACK
F. & R. - T.C.=o
SIDE - T.C.=o

SEAT CUSHION
T. & B. - T.C.=o
(IMBEDDLD ONE INCH
ON BOTTOM SIDE)

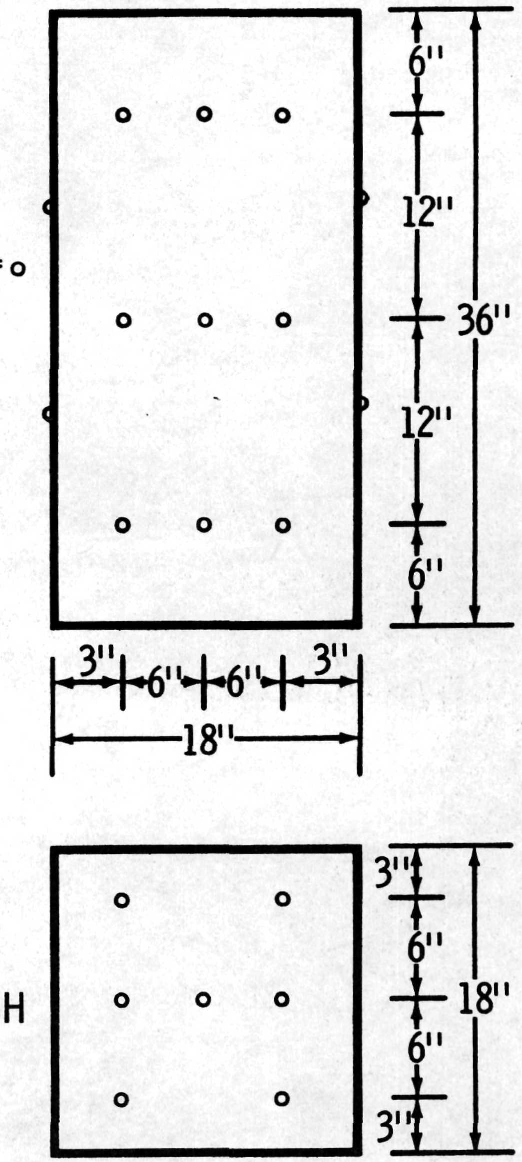

Fig. 2

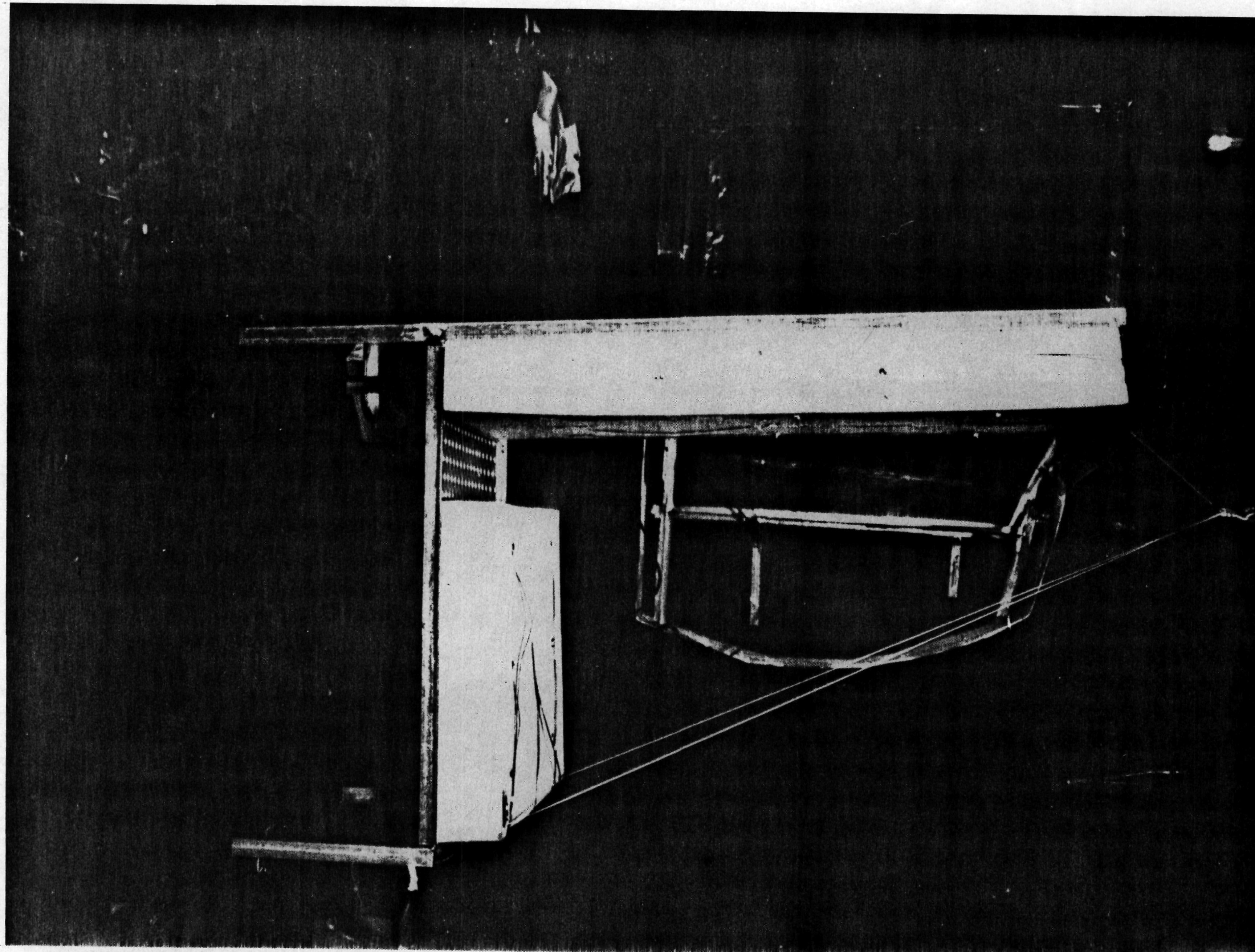

Fig. 3

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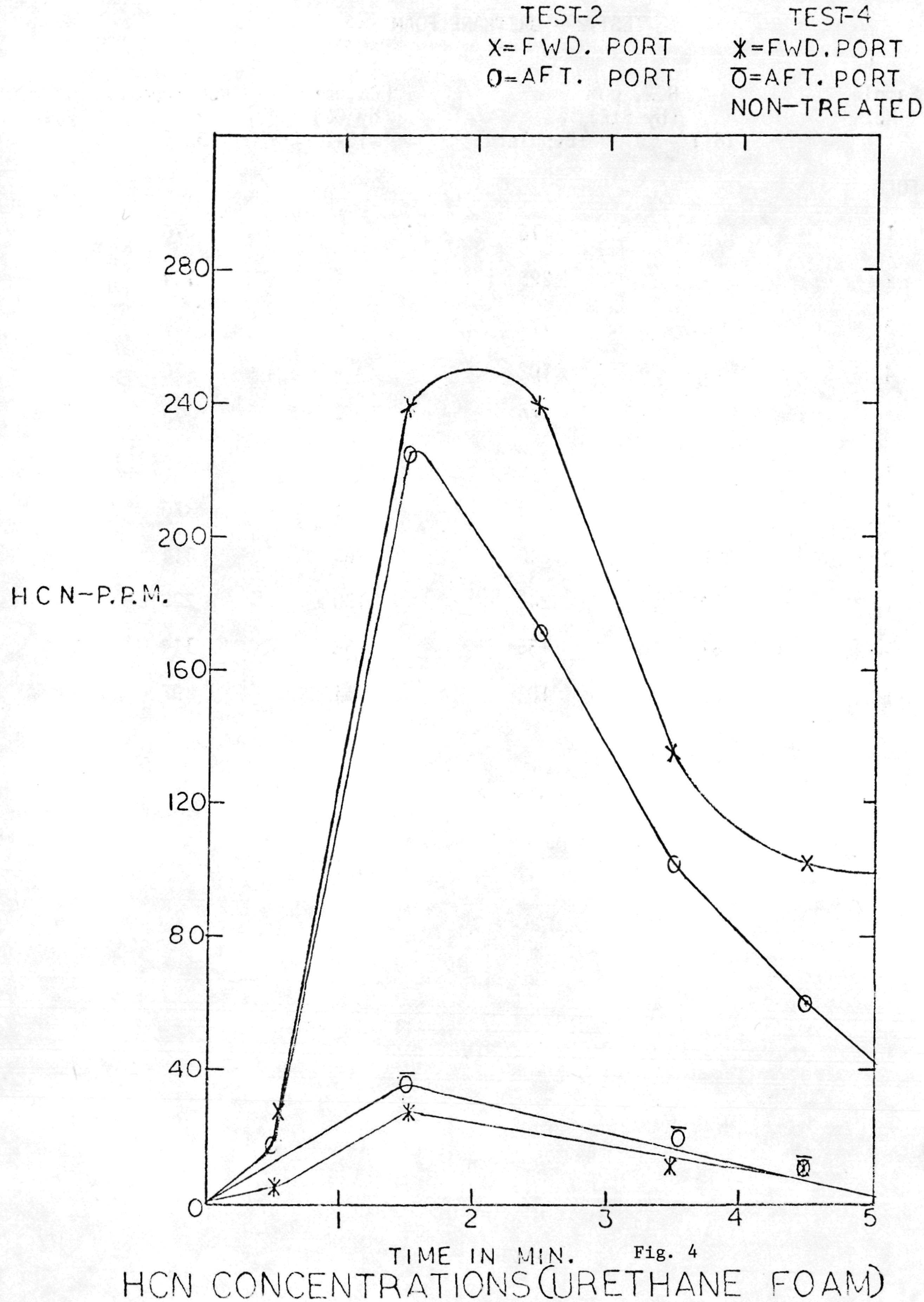

Fig. 4

HCN CONCENTRATIONS (URETHANE FOAM)

TEST 2 - URETHANE FOAM

Sample No.	HCN, ppm (by SIE) 16-1	Bubblers	HCN,ppm (by GC) 16-1	HCN, ppm (by IR) 32-1
FORE				
1	-	16	-	<70
2	-	225	-	154
3	-	171	-	86
4	-	102	-	<70
5	-	60	-	<70
AFT				
1	<6	13	<1	<70
2	272	240	165	314
3	210	240	130	228
4	87	135	68	114
5	56	102	54	97

Fig. 5

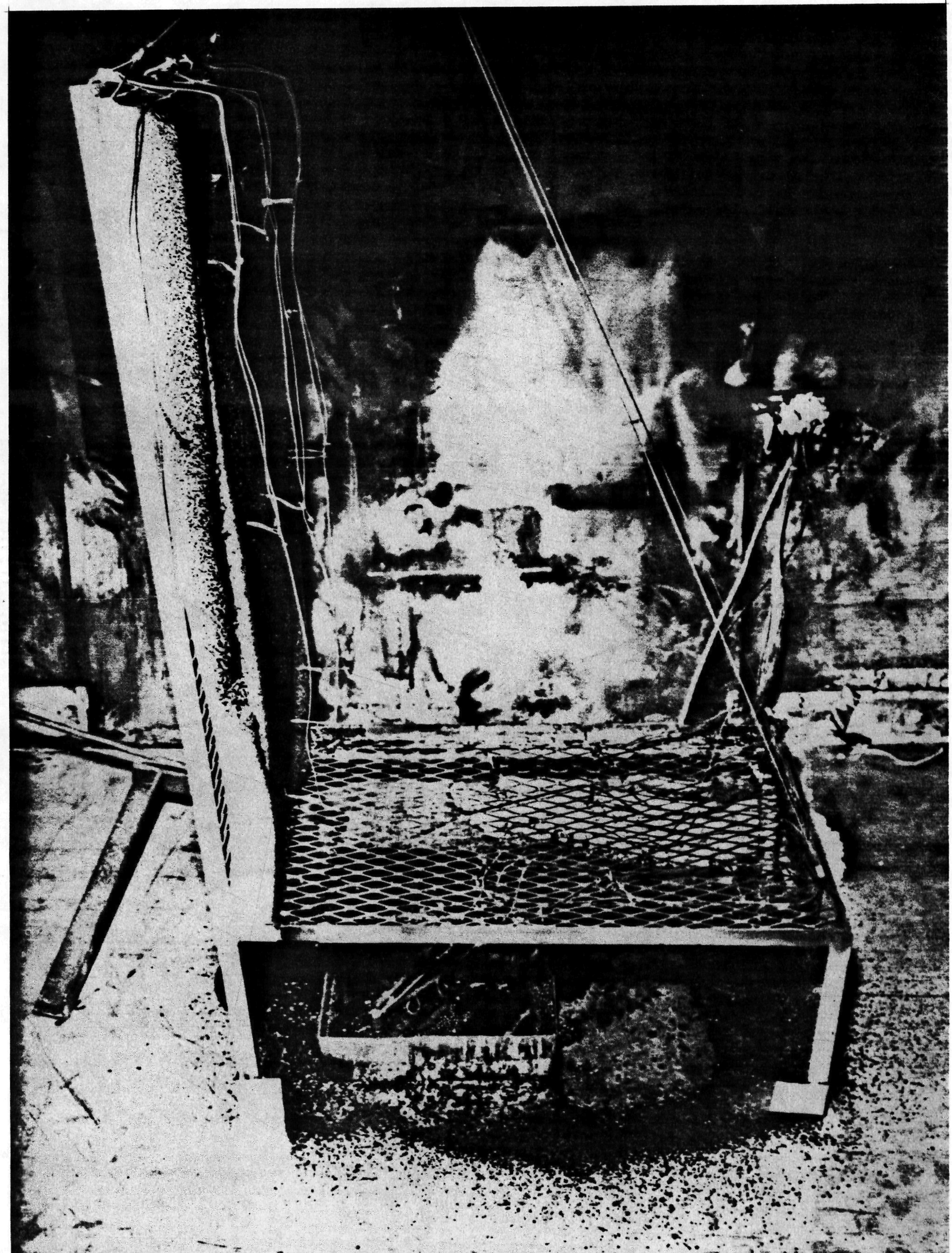

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Fig. 9

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SEAT FOAM TEST

SELECTED T.C.'s

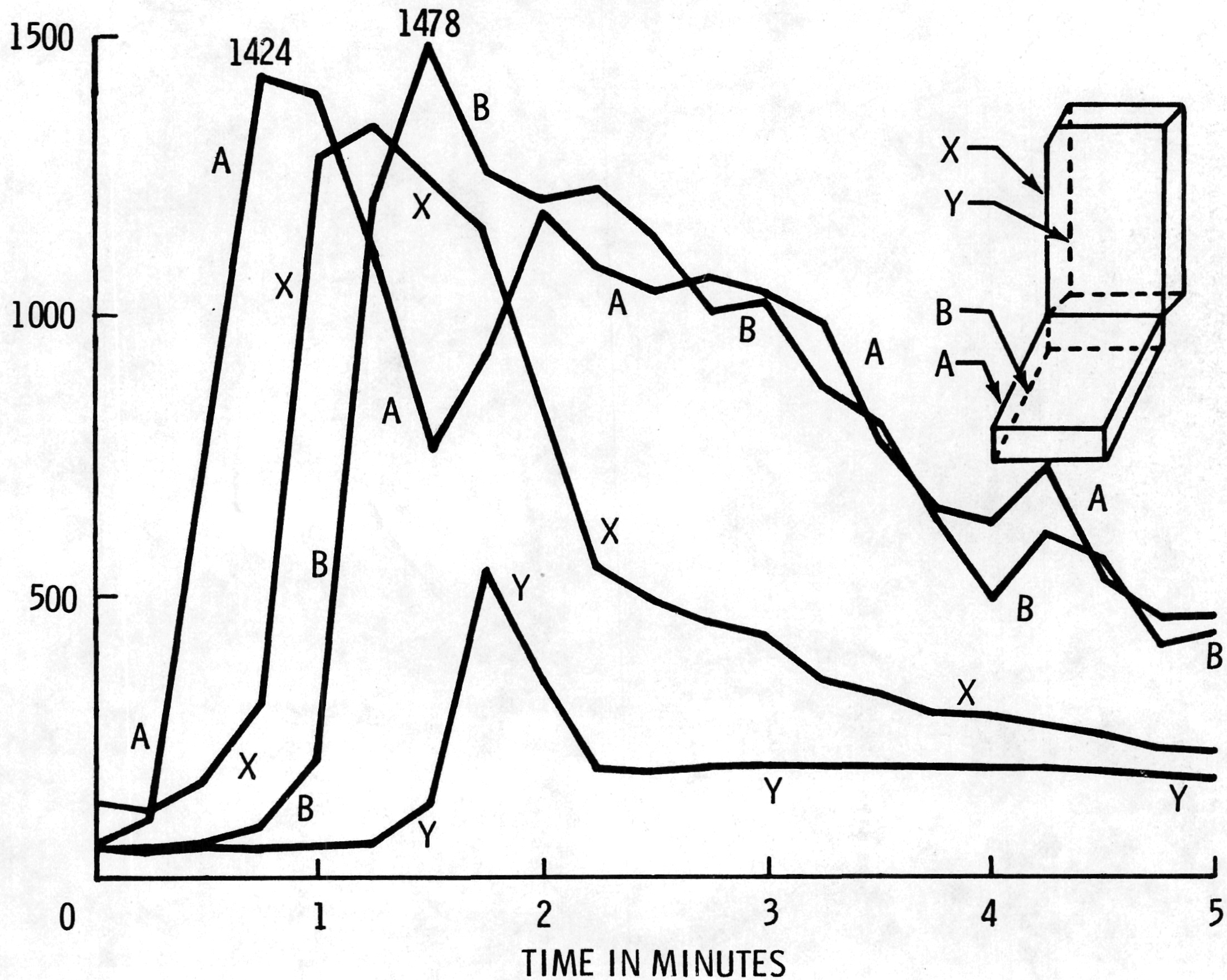

Fig. 7

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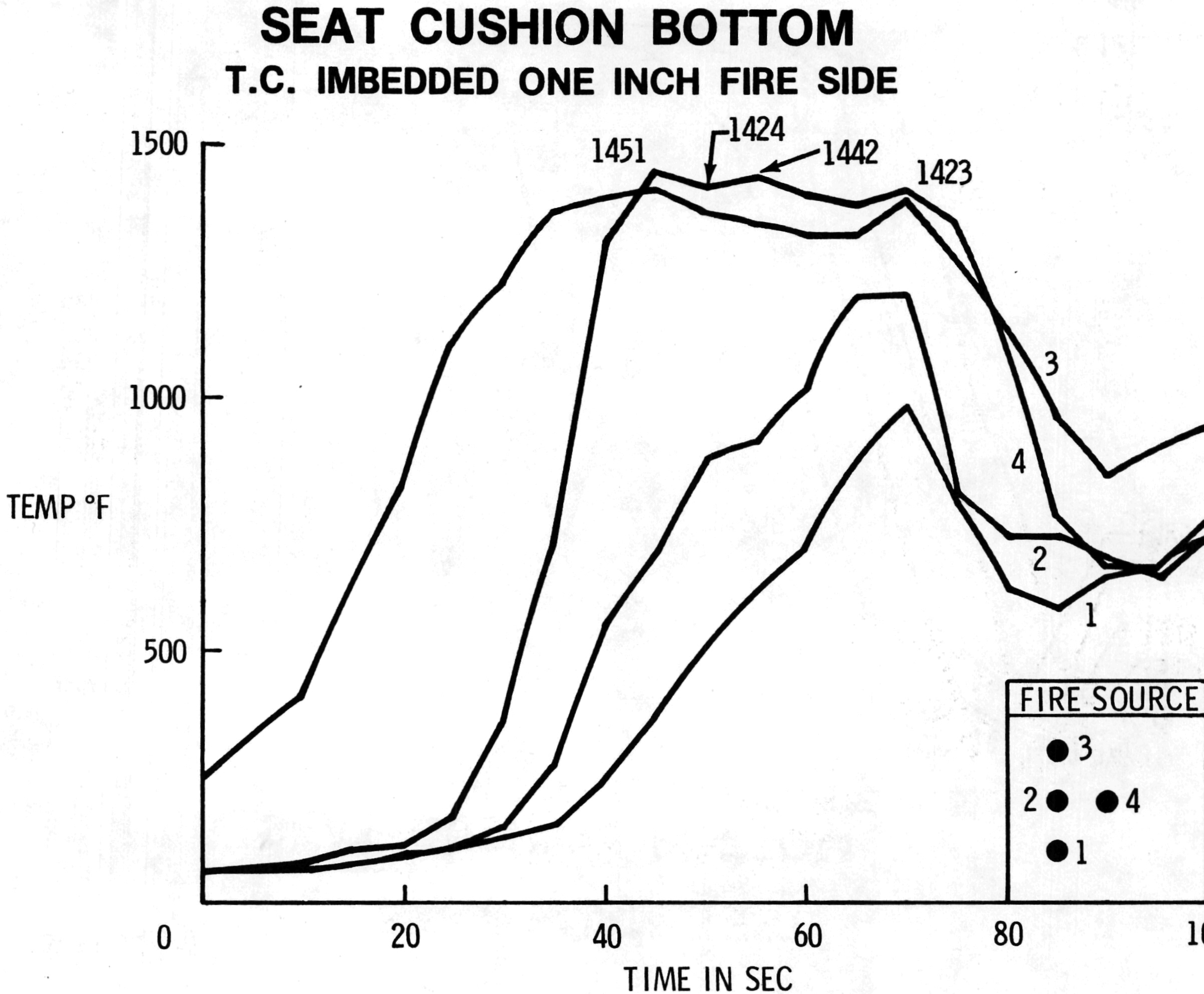

Fig. 8

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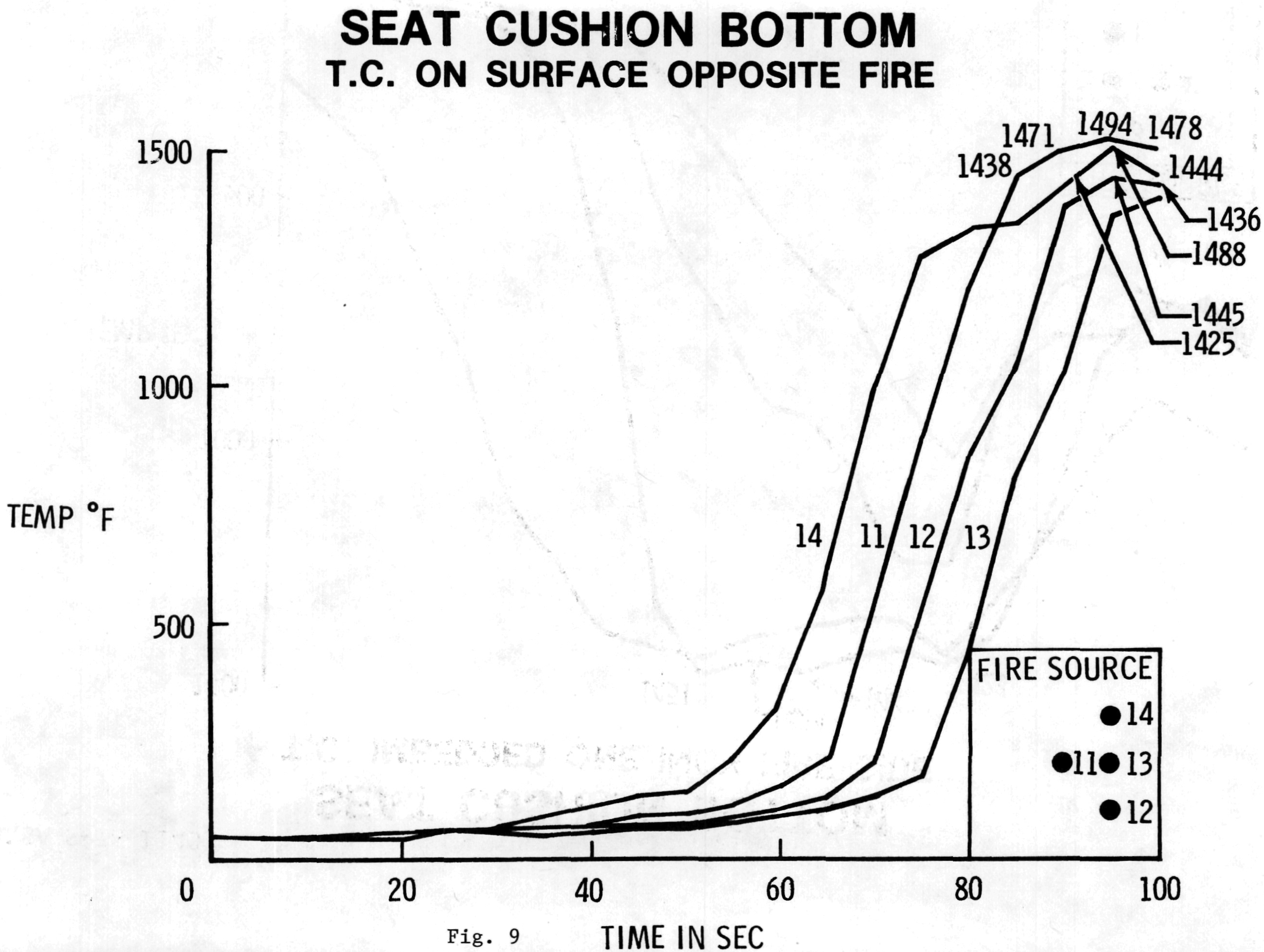

Fig. 9

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SEAT CUSHION BACK
T.C. ON SURFACE FIRE SIDE

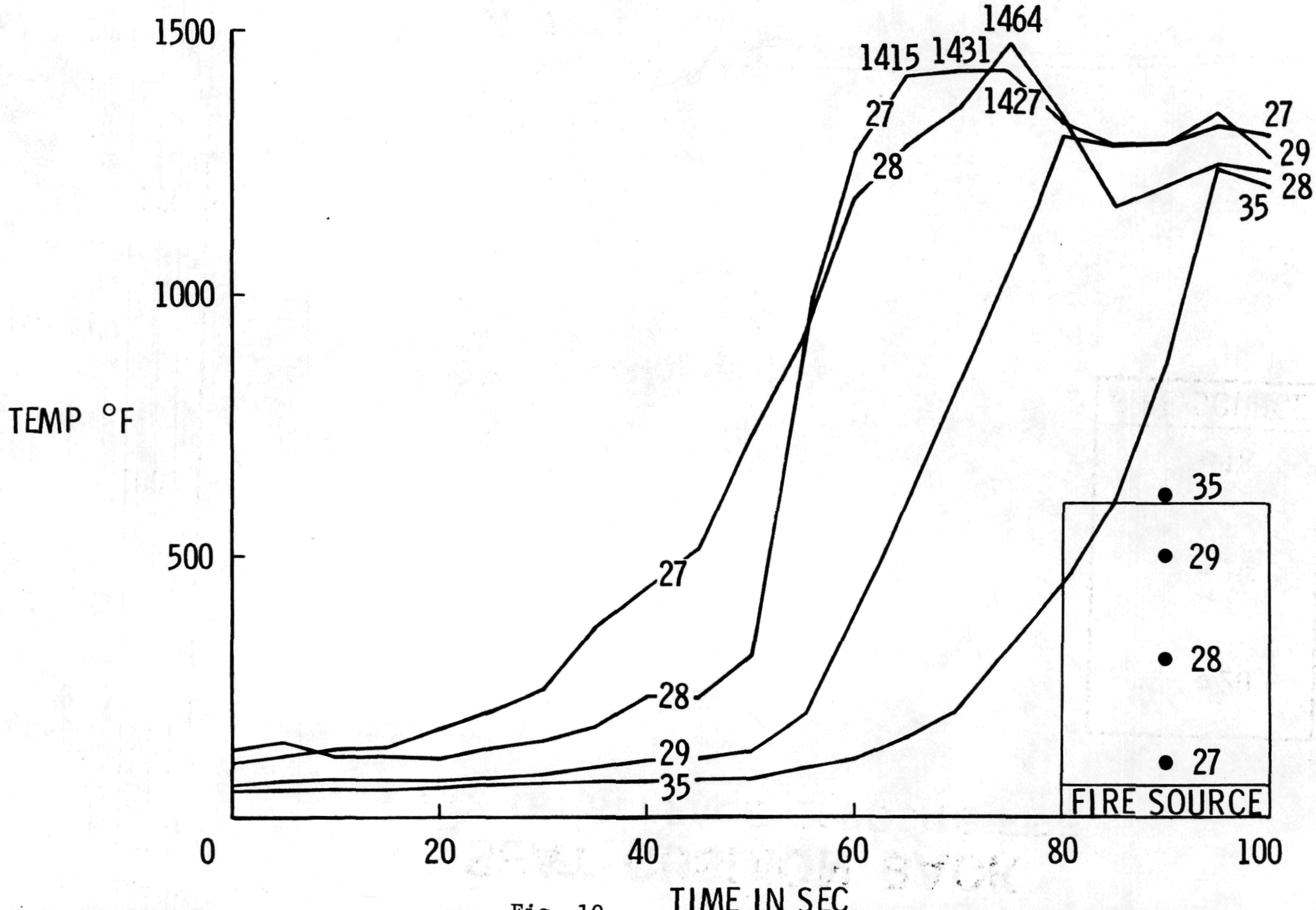

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Fig. 10

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SEAT CUSHION BACK
T.C. ON SURFACE OPPOSITE FIRE

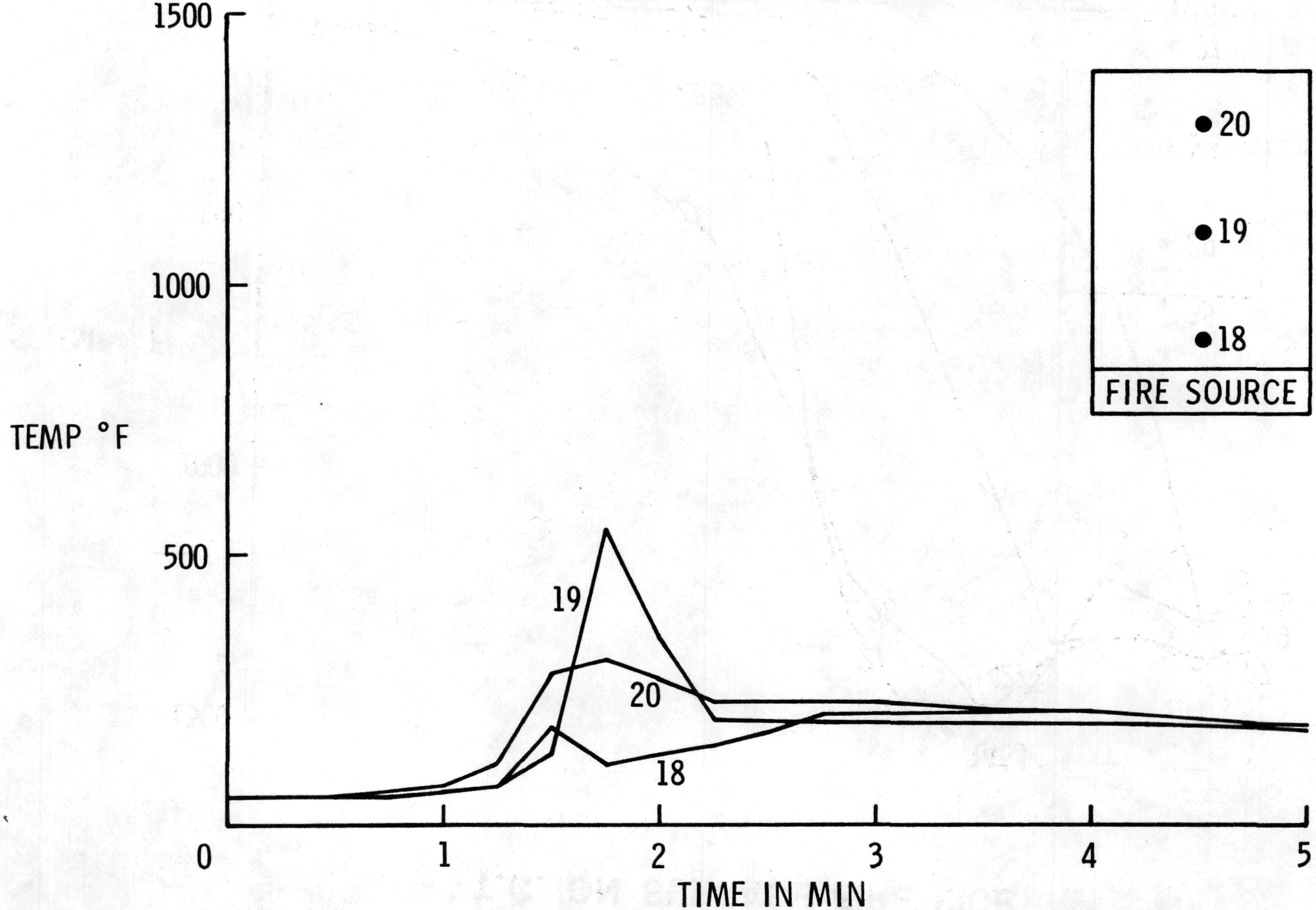

Fig. 11

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SEAT FOAM TEST
20′ SECTION T.C.

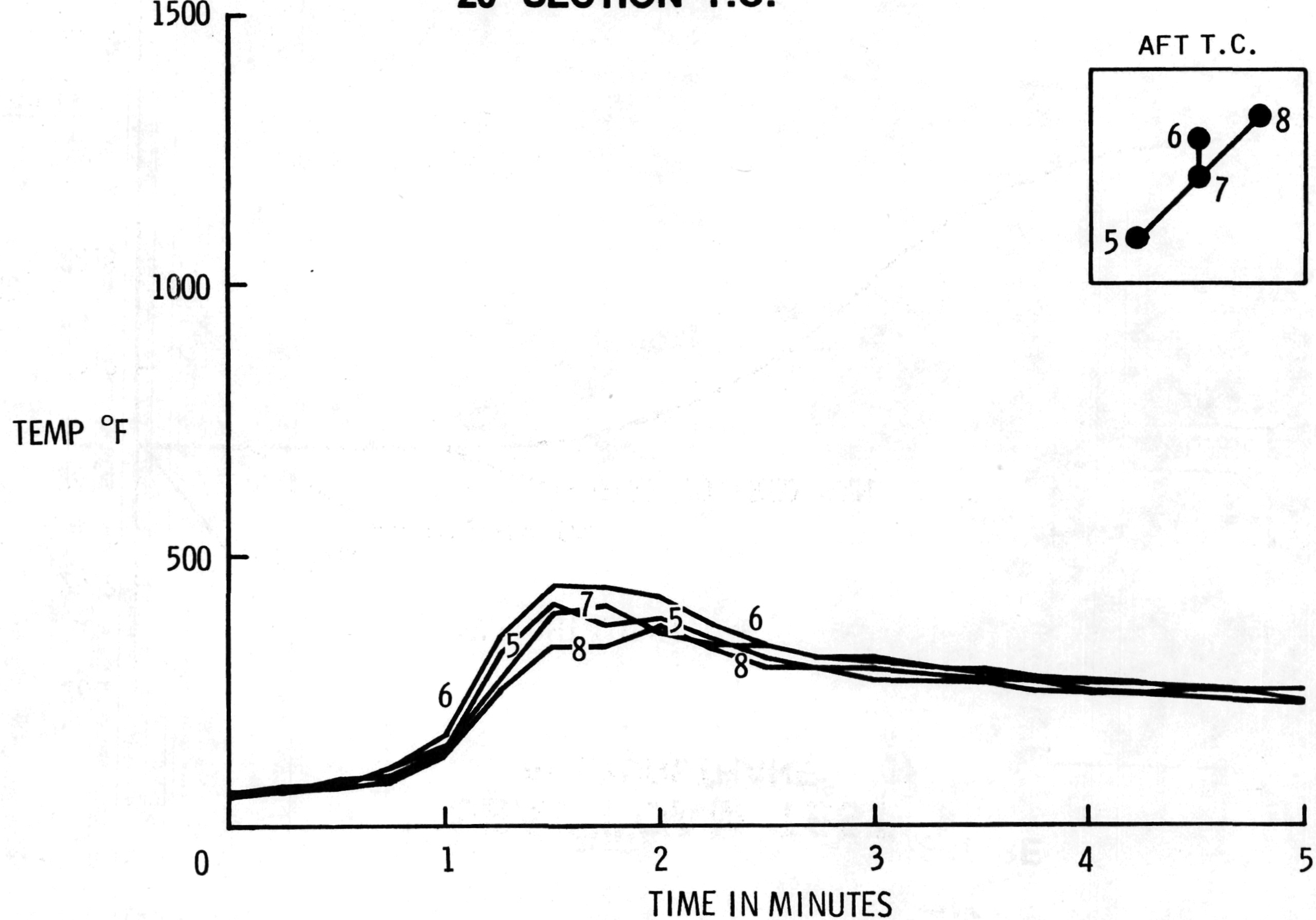

Fig. 12

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SEAT FOAM TEST
POLYURETHANE

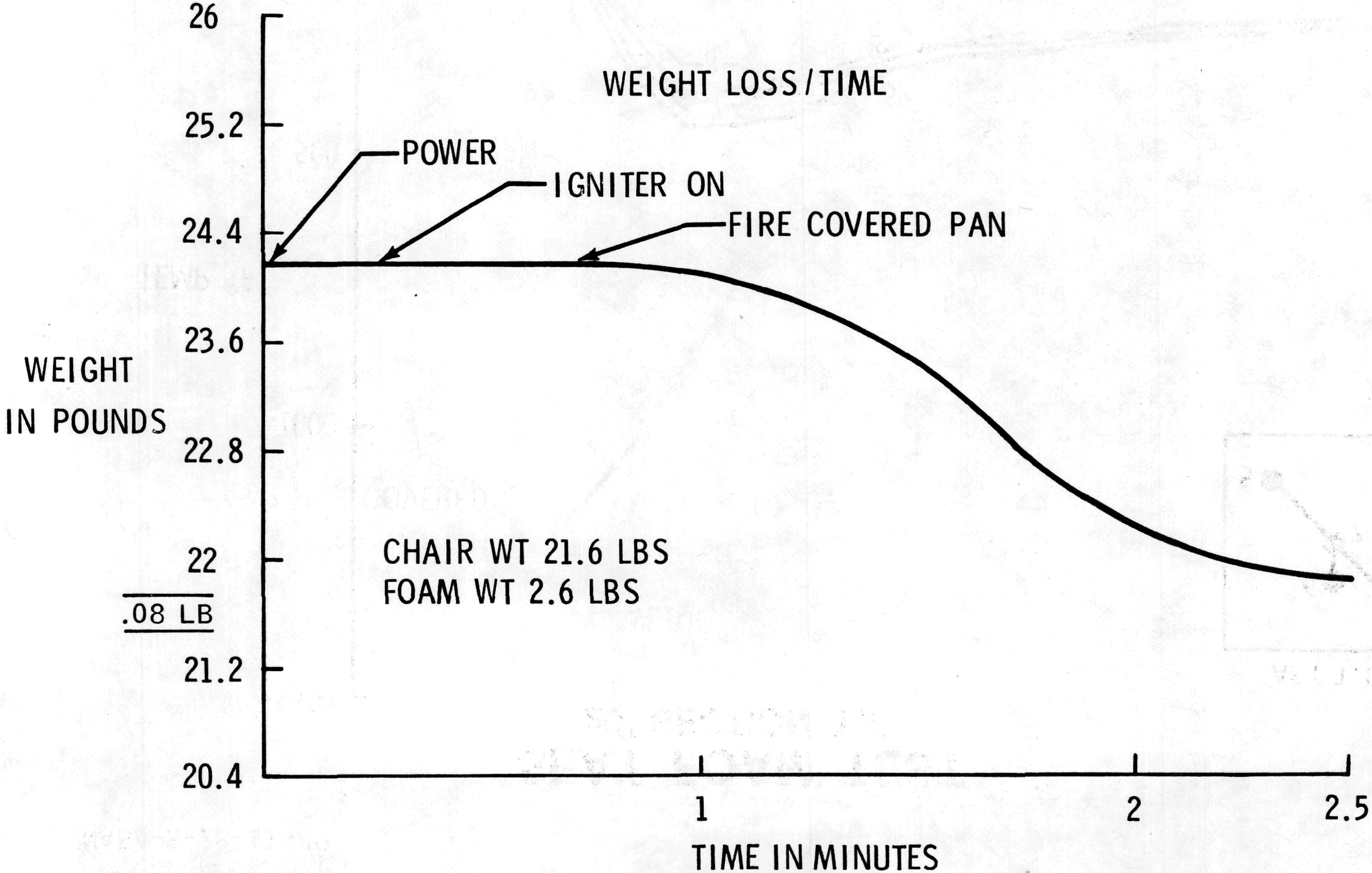

Fig. 13

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FUEL PAN TEST (JET A-1) 2.5 LITERS

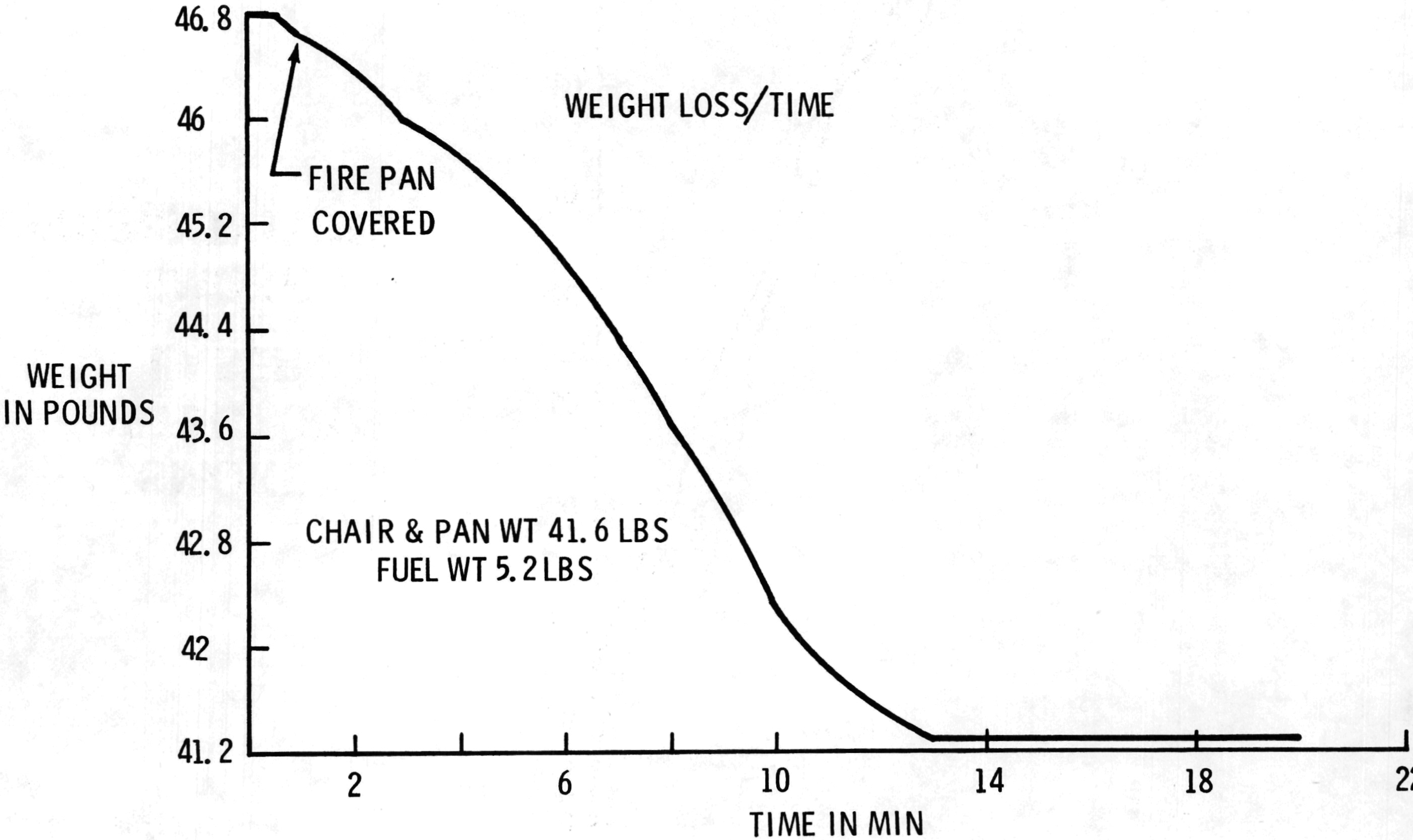

Fig. 14

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SMOKE DETECTOR/ LASER

SMOKE DENSITY/TIME

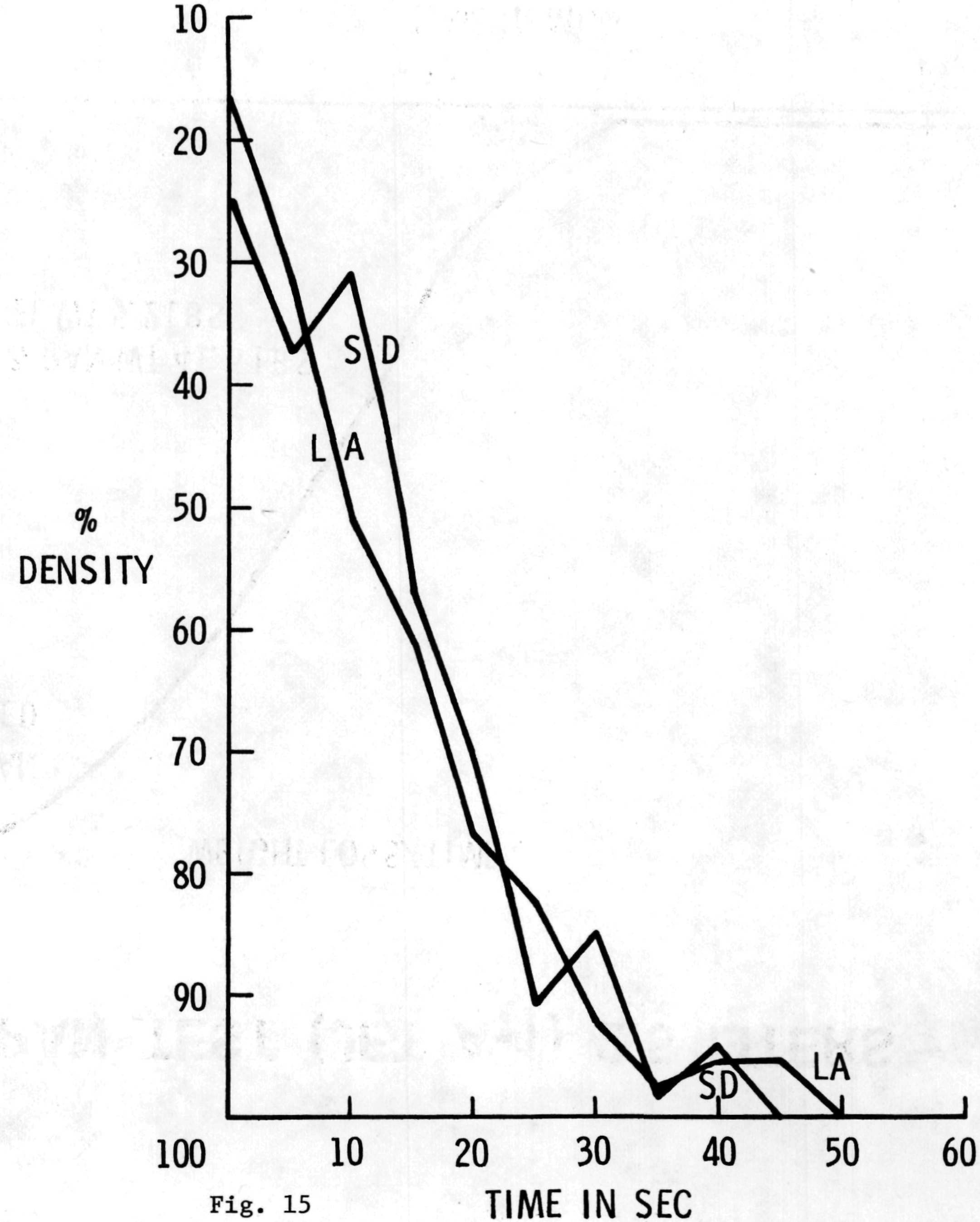

Fig. 15